90-day mortality after 409 096 total hip replacements for osteoarthritis, from the National Joint Registry for England and Wales: a retrospective analysis

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Summary

Background Death within 90 days after total hip replacement is rare but might be avoidable dependent on patient and treatment factors. We assessed whether a secular decrease in death caused by hip replacement has occurred in England and Wales and whether modifiable perioperative factors exist that could reduce deaths.

Methods We took data about hip replacements done in England and Wales between April, 2003, and December, 2011, from the National Joint Registry for England and Wales. Patient identifiers were used to link these data to the national mortality database and the Hospital Episode Statistics database to obtain details of death, sociodemographics, and comorbidity. We assessed mortality within 90 days of operation by Kaplan-Meier analysis and assessed the role of patient and treatment factors by Cox proportional hazards model.

Findings 409 096 primary hip replacements were done to treat osteoarthritis. 1743 patients died within 90 days of surgery during 8 years, with a substantial secular decrease in mortality, from 0·56% in 2003 to 0·29% in 2011, even after adjustment for age, sex, and comorbidity. Several modifiable clinical factors were associated with decreased mortality according to an adjusted model: posterior surgical approach (hazard ratio [HR] 0·82, 95% CI 0·73–0·92; p=0·001), mechanical thromboprophylaxis (0·85, 0·74–0·99; p=0·036), chemical thromboprophylaxis with heparin with or without aspirin (0·79, 0·66–0·93; p=0·005), and spinal versus general anaesthetic (0·85, 0·74–0·97; p=0·019). Type of prosthesis was unrelated to mortality. Being overweight was associated with lower mortality (0·76, 0·62–0·92; p=0·006).

Interpretation Postoperative mortality after hip joint replacement has fallen substantially. Widespread adoption of four simple clinical management strategies (posterior surgical approach, mechanical and chemical prophylaxis, and spinal anaesthesia) could, if causally related, reduce mortality further.

Funding National Joint Registry for England and Wales.

Lancet 2013; 382: 1097–104

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Introduction

Although death as a result of total hip joint replacement is rare, the risk still needs to be quantified and minimised through reduction of risk factors. The UK National Institute for Health and Care Excellence has recommended several measures to reduce postoperative mortality,[1] including use of mechanical and chemical thromboprophylaxis. However, obtaining good evidence about the effectiveness of preventive measures is difficult because mortality is low.

The National Joint Registry for England and Wales, established in April, 2003, records all total hip replacements done in England and Wales, the Office for National Statistics records all deaths in England and Wales, and the Hospital Episode Statistics records all inpatient recipients of NHS-funded care in England. Combination of these datasets provides an opportunity to assess many aspects of care in total hip replacement and their association with mortality. Additionally, the effect of patient factors on mortality can be studied.

We analysed postoperative mortality after hip replacement for osteoarthritis with the aims of: estimating the risk of mortality after hip replacement, assessing whether mortality after hip replacement has decreased with time, and identifying which treatment factors are associated with reduced mortality after accounting for patient factors.

Methods

Data sources

In this retrospective observational study we analysed data from the National Joint Registry. Details from the National Joint Registry of patients who had had primary total hip replacement were passed to the NHS Personal Demographics Service, which provided dates of death from the Office for National Statistics if the NHS number was traceable. National Joint Registry data were also linked to inpatient and day case records from Hospital Episode Statistics. We produce part 3 of the annual report of the National Joint Registry and in that capacity receive the appropriate dataset each year in April. Our Hospital Episode Statistics dataset was obtained at the same time as the National Joint Registry dataset was extracted in April, 2012, but contained no entries after Sept 30, 2011. Our base series was 458 568 primary hip operations—done between April 1, 2003, and Dec 31, 2011—with valid

person-level identifiers. Of these operations, we included 414 130 for which the only reason for surgery was osteoarthritis. We further excluded simultaneous bilateral operations (4882 operations, 2441 patients), 119 for which the patient's NHS number was not traceable (thus, we could not ascertain their date of death), and a further 33 for which consent had been withdrawn. Our results are based on the remaining 409 096 operations.

We obtained Hospital Episode Statistics for records with procedure codes related to primary hip replacement procedures (OPCS 4) within the National Joint Registry. For the patients identified, data were extracted about episode histories for hospital admissions for any reason. We then merged the National Joint Registry and Hospital Episode Statistics datasets. Hospital Episode Statistics histories were restricted to the 5 years before the primary operation. 64 695 of 409 096 (16%) of the hip operations in the National Joint Registry were privately funded and the funding source was uncertain for 23 147 of 409 096 (6%); all these cases were included in the main analysis. Hospital Episode Statistics episodes were available for three-quarters of the cohort (307 919 operations). Of the remaining 101 177 operations, 54 190 (54%) were privately funded and a further 5468 (5%) had an unknown funding source. The remaining 41 519 patients (10% of the whole cohort) had NHS operations but with no records in Hospital Episode Statistics. 8162 of these patients had operations after Sept 30, 2011.

See Online for appendix

Procedures

We assessed factors related to time to death from any cause, censoring at the end of December, 2011. We investigated several variables: surgical approach, implant type and fixation, anaesthetic type, thromboprophylaxis, age, sex, and body-mass index, which were all available in the National Joint Registry. We used several measures of comorbidity as potential confounders. The National Joint Registry provided the American Society of Anesthesiologists six point scale of surgical fitness. In addition, we used the Hospital Episode Statistics data to assess the number of hospital admissions for non-National Joint Registry related procedures in the 5 years before the primary operation (grouped as 0, 1–4, 5–9, and ≥10). We also used the International Classification of Diseases 10 codes reported in any hospital episode up to, and including, the primary operation, to define 16 high-risk subgroups with greater than expected mortality, as proposed by Charlson and colleagues.[2,3] To mitigate potential bias, calculation of comorbidity was restricted to operations on or before Sept 30, 2011. The appendix shows further details. We did not assess the effect of HIV/AIDS since only 19 patients had this infection and none died. We also extracted data about ethnic origin and area deprivation score from Hospital Episode Statistics. If the coding of a person's ethnic origin was inconsistent, we used the ethnic group stated most frequently. We used the Lower Super Output Areas Level (SOAL)—as defined by the Office for National Statistics—closest in time to the date of the primary operation as our geographical unit of analysis. SOAL was then linked to the English Indices of Multiple Deprivation for 2007,[4] and patients were characterised according to the area quintile in which they resided (1=most deprived area, 5=least deprived).[4]

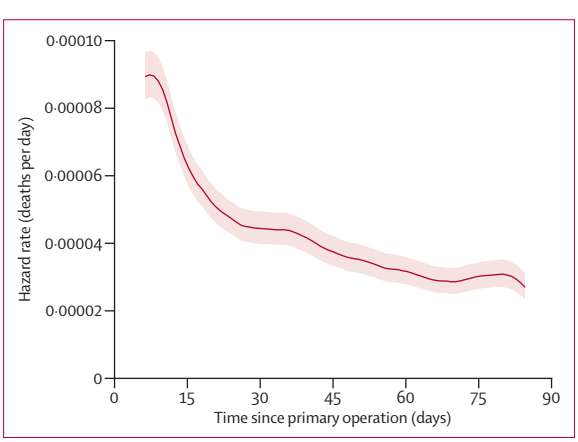

Figure 1: **Smoothed hazard rate showing how the risk of death changed over the first 90 days**
Smoothing calculated from changes in the Nelson-Aalen cumulative hazard estimates and smoothed with band half-width 5 days; shaded area represents 95% CI.

Statistical analysis

We used Kaplan-Meier estimates to describe the 90-day mortality of different sex and age groups. We used Cox proportional hazards models to investigate the effects of different patient and treatment factors, as well as time period, on the risk of death within 90 days. Age (grouped) and sex were included in all models. We used univariable models to separately assess the effects of year of operation, American Society of Anesthesiologists scale score, surgical approach, mechanical and chemical thromboprophylaxis, anaesthetic used, and implant type. We also made a multivariable model including all these factors, in which we assessed interactions between (1) age and sex, (2) mechanical and chemical thromboprophylaxis, and (3) year of operation and approach, thrombophylaxis, and anaesthetic. We checked proportionality of hazards graphically by eye. The multivariable model was repeated with further adjustment for comorbidity, body-mass index, and comorbidity in conjunction with ethnic origin and social deprivation area.

We did a series of multiple imputations for missing data, assuming that data were missing at random, with the ICE procedure in Stata (version 12). The imputation models included all predictor variables for the Cox model, together with the outcome variable (Nelson-Aalen estimate and whether or not patient died) because they carried information about missing values of the predictors. We also added other covariates that could help with the imputation model (appendix).

Role of the funding source

The sponsor of the study had no role in the study design, data collection, data analysis, data interpretation, or writing of the final report. LPH had full access to all the data in the study and AWB had final responsibility for the decision to submit for publication.

Results

Over the 8 years of follow-up available for the whole cohort, the hazard rate increased with time from operation (data not shown), with steeper slopes for men and older age groups, as expected for normal ageing, especially in view of the ages of patients at primary operation (mean 68·4, SD 10·6 years). 1743 patients died in the first 90 days after surgery. The hazard rate within the first 90 days (figure 1) suggests a short-term peak risk of death in the perioperative period that then subsided.

90-day mortality increased with age and was higher in men than in women (table 1). Mortality decreased over the study period (from 0·56% in 2003, to 0·29% in 2011) and after adjustment for age and sex the relative risk halved over the 8 years (for 2011 *vs* 2003 hazard ratio 0·49, 95% CI 0·37–0·65; p<0·001; table 2, figure 2). Some of this change is a result of the secular fall in mortality but, even accounting for age-specific, sex-specific, and period-specific mortality rates (table 2), mortality still fell substantially (ratio of ratios 0·65).

Table 3 shows results of the univariable and multivariable analyses. In the univariable analysis, we detected no significant interactions between age and sex (p=0·79) or between mechanical and chemical prophylaxis (p=0·66). The effects of approach, mechanical and chemical thromboprophylaxis, and anaesthetic did not change significantly across the three year groups ($p_{interaction}$=0·08 to >0·99). Graphical checking confirmed proportional hazards for age group and sex, and all other variables. The univariable analyses were unchanged with a series of complete case analyses, based on the dataset in the multivariable analysis adjusted for sex and age group (data not shown).

We adjusted for comorbidities with both number of admissions to hospital in the preceding 5 years and comorbidity Charlson subgroups, but after adjustment for Charlson subgroups there was no benefit of additional adjustment for number of admissions. Likewise, further adjustment by body-mass index, ethnic origin, and area deprivation did not alter the results significantly (appendix).

We did a sensitivity analysis by repeating the multivariable analysis adjusted for age and sex but using deaths up to only 30 days (data not shown). Fewer patients died in this period (882, or half the number up to 90 days in the multivariable analysis), meaning that the power was reduced. Posterior approach and thrombophylaxis still had significant effects on mortality; anaesthetic effects, however, were not significant.

Four treatment variables were associated with decreased mortality within 10 days of surgery in each model: spinal

	Patients (n)	Deaths (n)	Kaplan-Meier estimate of deaths at 90 days (95% CI)
Men			
<55 years	21 247	17	0·08% (0·05–0·13)
55–59 years	17 419	20	0·12% (0·08–0·18)
60–64 years	26 330	48	0·18% (0·14–0·24)
65–69 years	29 201	99	0·34% (0·28–0·41)
70–74 years	30 988	139	0·45% (0·38–0·54)
75–79 years	23 938	175	0·74% (0·64–0·86)
≥80 years	17 343	327	1·90% (1·71–2·11)
Women			
<55 years	19 678	10	0·05% (0·03–0·10)
55–59 years	19 603	20	0·10% (0·07–0·16)
60–64 years	31 939	40	0·12% (0·09–0·17)
65–69 years	41 128	71	0·17% (0·14–0·22)
70–74 years	47 172	127	0·27% (0·23–0·32)
75–79 years	41 871	186	0·45% (0·39–0·52)
≥80 years	41 239	464	1·13% (1·03–1·23)

Table 1: **90-day mortality by age and sex**

For the **mortality risk data from the Office for National Statistics** see http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-276237

	Operations (n)	Deaths within 90 days (n)	Expected number of deaths*	Actual/ expected number of deaths	Kaplan-Meier estimate of deaths at 90 days	Hazard ratio (95% CI)†
2003	12 621	72	97	0·74	0·56%	1·00
2004	24 723	139	178	0·78	0·56%	0·99 (0·74–1·31)
2005	35 665	176	254	0·69	0·49%	0·86 (0·66–1·13)
2006	42 212	222	293	0·76	0·52%	0·91 (0·70–1·19)
2007	53 526	247	366	0·68	0·46%	0·81 (0·62–1·05)
2008	58 493	253	398	0·64	0·42%	0·75 (0·58–0·97)
2009	59 706	247	386	0·64	0·41%	0·71 (0·55–0·92)
2010	61 423	223	397	0·56	0·36%	0·61 (0·47–0·80)
2011	60 727	164	342	0·48	0·29%	0·49 (0·37–0·65)

*Calculated from data for mortality risk by age, sex, and year from the Office for National Statistics. †Adjusted for sex and age, relative to 2003.

Table 2: **Changes in mortality by year of primary operation**

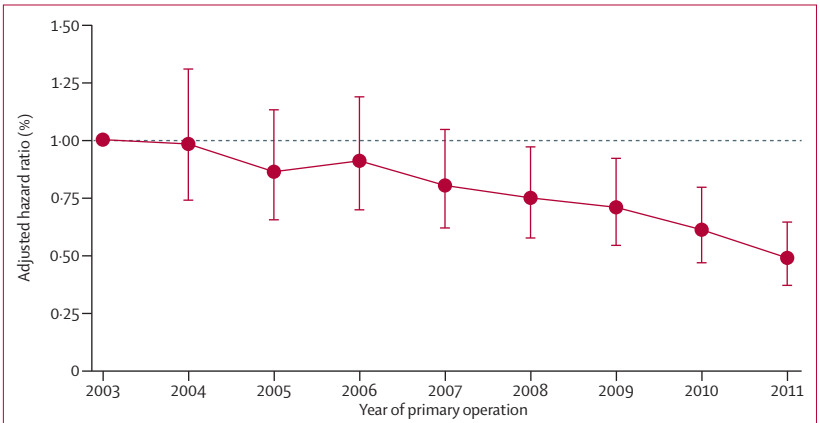

Figure 2: **Changes in mortality over time**
Hazard ratios with 95% CIs for each year of primary operation after adjustment for sex and age.

	Univariable analysis (adjusted for sex and age group)			Multivariable analysis (adjusted for sex and age group)*		Multivariable analysis (adjusted for sex, age group, and comorbidity)†	
	n	Hazard ratio (95% CI)	p value	Hazard ratio (95% CI)	p value	Hazard ratio (95% CI)	p value
Year of primary operation							
2003–05	73 009	1·00 (reference)	NA	1·00 (reference)	NA	1·00 (reference)	NA
2006–08	154 231	0·88 (0·77–0·99)	0·036	0·90 (0·79–1·03)	0·12	0·85 (0·73–0·98)	0·031
2009–11	181 856	0·65 (0·57–0·74)	<0·0005	0·71 (0·62–0·82)	<0·0005	0·64 (0·54–0·75)	<0·0005
ASA physical status							
P1	79 098	1·00 (reference)	NA	1·00 (reference)	NA	1·00 (reference)	NA
P2	275 671	1·18 (0·99–1·41)	0·058	1·31 (1·09–1·58)	0·004	1·28 (1·02–1·60)	0·031
P3	52 419	2·79 (2·32–3·36)	<0·0005	3·09 (2·55–3·76)	<0·0005	2·08 (1·64–2·63)	<0·0005
P4 or P5	1908	6·31 (4·60–8·67)	<0·0005	6·83 (4·95–9·42)	<0·0005	2·57 (1·77–3·75)	<0·0005
Approach							
Not posterior	201 599	1·00 (reference)	NA	1·00 (reference)	NA	1·00 (reference)	NA
Posterior	207 466	0·78 (0·71–0·86)	<0·0005	0·82 (0·74–0·91)	<0·0005	0·82 (0·73–0·92)	0·001
Missing data	31	..	..	..	..	..	..
Mechanical prophylaxis							
No	58 556	1·00 (reference)	NA	1·00 (reference)	NA	1·00 (reference)	NA
Yes	349 321	0·76 (0·67–0·86)	<0·0005	0·84 (0·74–0·96)	0·011	0·85 (0·74–0·99)	0·036
Missing data	1219	..	..	..	..	..	..
Chemical prophylaxis							
None	49 451	1·00 (reference)	NA	1·00 (reference)	NA	1·00 (reference)	NA
Aspirin (only)	50 203	0·88 (0·73–1·05)	0·16	0·90 (0·75–1·08)	0·27	0·92 (0·74–1·14)	0·43
Heparin only or with aspirin	262 043	0·79 (0·69–0·90)	0·001	0·80 (0·69–0·92)	0·002	0·79 (0·66–0·93)	0·005
Other or other combinations	46 180	0·75 (0·62–0·91)	0·003	0·85 (0·69–1·04)	0·11	0·91 (0·72–1·15)	0·45
Missing data	1219	..	..	..	..	..	..
Anaesthetic							
General only	96 433	1·00 (reference)	NA	1·00 (reference)	NA	1·00 (reference)	NA
Spinal only	165 807	0·87 (0·77–0·98)	0·024	0·86 (0·76–0·97)	0·012	0·85 (0·74–0·97)	0·019
Epidural only	14 723	1·18 (0·93–1·49)	0·18	1·10 (0·87–1·39)	0·42	0·97 (0·74–1·26)	0·81
Nerve block only	3032	1·47 (0·95–2·28)	0·083	1·41 (0·91–2·18)	0·13	1·56 (0·99–2·45)	0·055
Spinal and general	49 989	0·76 (0·64–0·91)	0·003	0·80 (0·67–0·96)	0·017	0·74 (0·60–0·91)	0·005
Spinal and epidural	6509	1·28 (0·93–1·76)	0·14	0·99 (0·72–1·37)	0·97	0·84 (0·59–1·19)	0·33
Spinal and nerve block	10 424	0·65 (0·46–0·93)	0·017	0·66 (0·46–0·95)	0·023	0·65 (0·44–0·96)	0·032
General and epidural	16 563	1·14 (0·90–1·45)	0·27	1·02 (0·80–1·29)	0·89	0·93 (0·71–1·22)	0·61
General and nerve block	29 707	0·92 (0·75–1·12)	0·40	0·87 (0·71–1·06)	0·16	0·78 (0·62–0·98)	0·035
Other	3259	0·75 (0·41–1·37)	0·35	0·70 (0·39–1·28)	0·25	0·80 (0·43–1·51)	0·49
Missing data	12 650	..	..	..	..	..	..
Hip replacement type							
Cemented MoP	142 002	1·00 (reference)	NA	1·00 (reference)	NA	1·00 (reference)	NA
Cemented CoP	12 045	0·79 (0·55–1·11)	0·18	0·85 (0·59–1·21)	0·37	0·84 (0·54–1·30)	0·44
Uncemented MoP	54 960	0·82 (0·71–0·95)	0·008	0·92 (0·79–1·07)	0·26	0·96 (0·81–1·13)	0·61
Uncemented MoM	24 618	0·92 (0·72–1·17)	0·49	1·03 (0·81–1·32)	0·80	1·13 (0·85–1·50)	0·39
Uncemented CoP	20 109	0·79 (0·59–1·04)	0·092	0·81 (0·60–1·08)	0·15	0·96 (0·71–1·32)	0·82
Uncemented CoC	45 062	0·72 (0·57–0·92)	0·009	0·92 (0·71–1·17)	0·49	1·08 (0·81–1·43)	0·62
Uncemented CoM	1738	0·80 (0·30–2·14)	0·66	1·08 (0·40–2·90)	0·88	1·07 (0·34–3·35)	0·91
Hybrid MoP	41 124	1·00 (0·86–1·15)	0·99	1·08 (0·93–1·25)	0·32	1·08 (0·91–1·29)	0·37
Hybrid MoM	2159	0·87 (0·41–1·82)	0·70	1·01 (0·48–2·13)	0·98	1·15 (0·51–2·57)	0·74
Hybrid CoP	6327	0·70 (0·42–1·16)	0·17	0·80 (0·47–1·37)	0·42	0·85 (0·44–1·64)	0·62
Hybrid CoC	10 502	0·90 (0·58–1·40)	0·65	1·02 (0·64–1·63)	0·92	1·04 (0·59–1·81)	0·90
Reverse hybrid MoP	5765	0·78 (0·53–1·15)	0·20	0·83 (0·56–1·22)	0·34	0·88 (0·57–1·35)	0·55
Reverse hybrid CoP	2594	1·24 (0·66–2·31)	0·51	1·37 (0·71–2·65)	0·35	1·65 (0·82–3·33)	0·16

(Continues on next page)

	Univariable analysis (adjusted for sex and age group)			Multivariable analysis (adjusted for sex and age group)*		Multivariable analysis (adjusted for sex, age group, and comorbidity)†	
	n	Hazard ratio (95% CI)	p value	Hazard ratio (95% CI)	p value	Hazard ratio (95% CI)	p value
(Continued from previous page)							
Resurfacing MoM	30 264	0·53 (0·35–0·81)	0·003	0·64 (0·41–0·98)	0·041	0·98 (0·59–1·64)	0·95
Other or unknown	9827	1·09 (0·81–1·45)	0·57	1·14 (0·85–1·53)	0·39	1·03 (0·73–1·45)	0·89
Myocardial infarction‡							
No	295 049	..	..	..	..	1·00 (reference)	NA
Yes	8251	..	..	..	..	2·74 (2·34–3·22)	<0·0005
Congestive heart failure‡							
No	296 986	..	..	..	..	1·00 (reference)	NA
Yes	6314	..	..	..	..	2·62 (2·23–3·09)	<0·0005
Peripheral vascular disease‡							
No	297 732	..	..	..	..	1·00 (reference)	NA
Yes	5568	..	..	..	..	1·51 (1·22–1·88)	<0·0005
Cerebrovascular disease‡							
No	297 639	..	..	..	..	1·00 (reference)	NA
Yes	5661	..	..	..	..	1·79 (1·44–2·23)	<0·0005
Dementia‡							
No	302 317	..	..	..	..	1·00 (reference)	NA
Yes	983	..	..	..	..	1·54 (0·97–2·44)	0·068
Chronic pulmonary disease‡							
No	268 631	..	..	..	..	1·00 (reference)	NA
Yes	34 669	..	..	..	..	1·27 (1·10–1·47)	0·001
Connective tissue disease or rheumatic disease‡							
No	293 279	..	..	..	..	1·00 (reference)	NA
Yes	10 021	..	..	..	..	1·32 (1·05–1·66)	0·019
Peptic ulcer disease‡							
No	299 234	..	..	..	..	1·00 (reference)	NA
Yes	4066	..	..	..	..	1·87 (1·45–2·39)	<0·0005
Liver disease‡							
No	301 541	..	..	..	..	1·00 (reference)	NA
Mild	1427	..	..	..	..	1·70 (0·98–2·95)	0·057
Moderate or severe	332	..	..	..	..	9·70 (5·94–15·84)	<0·0005
Diabetes‡							
No	278 593	..	..	..	..	1·00 (reference)	NA
Without complications	23 441	..	..	..	..	1·13 (0·96–1·34)	0·14
With complications	1266	..	..	..	..	2·02 (1·35–3·02)	0·001
Paraplegia or hemiplegia‡							
No	302 244	..	..	..	..	1·00 (reference)	NA
Yes	1056	..	..	..	..	1·21 (0·73–2·02)	0·46
Renal disease‡							
No	296 648	..	..	..	..	1·00 (reference)	NA
Yes	6652	..	..	..	..	2·18 (1·83–2·60)	<0·0005
Cancer‡							
No	290 741	..	..	..	..	1·00 (reference)	NA
Cancer	10 962	..	..	..	..	1·08 (0·86–1·35)	0·53
Metastatic cancer	1597	..	..	..	..	7·19 (5·51–9·38)	<0·0005

Hip replacements can either be fixed to host bone with cement (cemented) or without cement (uncemented) or the femoral component can be cemented, but the acetabular component uncemented (hybrid) or the femoral component uncemented and the acetabular component cemented (reverse hybrid). Each hip replacement has two bearing surfaces that articulate against each other—either CoC, CoP, MoP, or MoM. CoP=ceramic on polyethylene. MoP=metal on polyethylene. MoM=metal on metal. CoC=ceramic on ceramic. NA=not applicable. ASA=American Society of Anesthesiologists. *395 410 patients had complete information, 1681 died within 90 days. †291 880 patients had complete information, 1336 died within 90 days. ‡No comorbidity data available for 105 796 patients with no Hospital Episode Statistics records or had no operations after Sept 30, 2011.

Table 3: **Univariable and multivariable Cox proportional hazards models of 90-day mortality**

anaesthetic or a combination of spinal and another anaesthetic, posterior approach, the use of mechanical thromboprophylaxis, and thromboprophylaxis with heparin with or without aspirin (table 3). The use of all four of these measures has increased steadily with time (appendix). However, the multivariable analyses showed that adjustment for these factors does not fully account for the decreased mortality over time. Had a posterior approach, mechanical and chemical prophylaxis, and a spinal anaesthetic only been used in every patient, deaths in 90 days would have been reduced from 0·43% to 0·34%—ie, by a fifth over the whole period, assuming that the associations are causal.

The National Joint Registry has had three phases of data entry that slightly differ in how surgical approach was described. Initially, variations of lateral and anterolateral approaches were not clearly distinguished. The most recent phase (since 2008) has 231 205 operations (56·5% of our entire cohort), of which 87 590 were done through a Hardinge approach and 128 867 through a posterior approach. A subgroup analysis of these cases (216 457 operations with 718 deaths within 90 days) showed that the posterior approach compared with the Hardinge approach had an HR of 0·85 (95% CI 0·74–0·98; p=0·03), adjusting for age and sex. Univariable analysis adjusting only for sex and age suggests a lower mortality with hip resurfacing arthroplasty, but type of hip replacement and bearing surface were unrelated to mortality in the adjusted multivariable analysis (table 3).

Worse general health—measured by American Society of Anesthesiologists score and some comorbidities—was associated with significantly increased risk of death. Severe liver disease was associated with an almost ten-times increase and metastatic cancer a seven-times increase, congestive cardiac failure and myocardial infarction with a two-to-three-times increase and renal disease with a two-times increase in relative risk of death within 90 days of surgery. In our fully adjusted model, being overweight at the time of surgery (body-mass index 26–30 kg/m²) was associated with lower 90-day mortality (HR 0·76, 95% CI 0·62–0·92; p=0.006) whereas being underweight (<19 kg/m²) was not associated with a change in 90-day mortality (HR 1·71, 95% CI 0·99–2·95; p=0·05) compared with patients with a normal body-mass index (19–25 kg/m²). The HR for those with a body-mass index greater than 30 kg/m² was 0·88 (95% CI 0·71–1·10; p=0·27). However, data for body-mass index were either missing from the National Joint Registry or the values were deemed out of range (<10 or >60 kg/m²) for 236 900 of 409 096 (57·9%) operations, and therefore these results should be interpreted with caution. Our reanalysis using several multiple imputation strategies produced almost identical results to the complete case analysis (appendix).

The number of hip replacements recorded in the National Joint Registry has risen substantially over the study period because of increased compliance, rather than increased activity. The National Joint Registry measures compliance by comparing the number of procedures entered in a year with implant sales in that year. Data for implant sales are provided by the manufacturers. Compliance has risen steadily from 64·7% (April, 2003–April, 2004) to 102% (April, 2011–April, 2012). The total number of hip and knee implants sold in 2003–04 was 459 797 compared with 509 297 in 2011–12.[5] Thus, according to implant sales, arthroplasties in England and Wales increased by only 10·8% over the entire study period. Furthermore, 2003 was an incomplete year because the registry began only in April, 2003.

Discussion

We have shown a large fall in early mortality after primary hip joint replacement for osteoarthritis between 2003, and 2011, which was unexpected. If deaths in the earlier period were systematically under-reported, this trend could be an artifact. However, we believe that this scenario is unlikely because most deaths occurred after registration; thus, any under-reporting should have been random and not related to future mortality. Additionally, we report a steady year-on-year fall, rather than a stepped decrease, which would be more likely if the trend was merely a result of registration practice. We adjusted for the variables most likely to affect mortality rates. However, our data do not include comprehensive information about comorbidities—fewer people might have had minor comorbidities that would contribute to early death, meaning that the general health of patients being operated on has improved, which could result in the decrease in mortality. The mortality trend might also be a result of a cohort effect—more recent generations of old people have greater compression of morbidity and are generally fitter and less frail than old people at the start of the study.[6] Likewise, other aspects of surgery and anaesthesia have improved sufficiently to account for the change in mortality rates.

Implant type did not affect perioperative mortality, but surgical approach, anaesthetic procedure, and thromboprophylaxis do seem to be important. Choice of surgical approach varies greatly between surgeons and orthopaedic units, on the basis of conventional practice, as well as concerns about outcomes and complications, but no clear data indicate that one is better than the other.[7] We have shown that the posterior approach is associated with lower mortality than with other approaches. We believe that the most likely reason for the difference is that the posterior approach results in more muscle preservation and therefore less bleeding[8] and better mobilisation than the commonest alternative, the lateral approach. Similarly, the use of different anaesthetic procedures is partly dictated by training and habit, although the general health of the patient, and specific issues such as severe spinal disease, are also important considerations.

Use of spinal anaesthetic was associated with lower mortality. The likely explanation is that spinal anaesthetic

lessens the need for general anaesthetic and immediate postoperative analgesia using morphine-like drugs that depress respiratory function, and thus the risk of postoperative pulmonary complications is reduced. Short-term complications—eg, infection and bleeding—after total knee replacement are rarer with spinal anaesthesia compared with general anaesthesia.[9] Case mix might account for some of the differences, because comorbidities will affect the decision about which anaesthetic procedure to use, but we adjusted data for American Society of Anesthesiologists score and comorbidities. However, we cannot exclude residual confounding as a possible explanation, so it seems appropriate to recommend a spinal anaesthetic when possible.

Chemical thromboprophylaxis is useful and is recommended by treatment guidelines.[1] Our analysis shows that mechanical and chemical thromboprophylaxis act independently and both reduce mortality. Thus, the use of both seems sensible. However, thromboprophylaxis could be harmful to some patients—eg, those with bleeding disorders—so its use should be based on the individual needs of the patient.

Comorbidities are important to immediate outcomes after joint replacement, including mortality. Our data show that some major comorbidities resulting in admission to hospital (and therefore detected through the Hospital Episode Statistics) were associated with much higher mortality rates than in patients without these comorbidities. Patients with severe liver disease, cancer, congestive heart failure, myocardial infarction, and renal disease were especially at risk of dying shortly after hip replacement, so efforts to reduce mortality should focus on those high-risk groups, and such patients should be counselled before surgery about mortality risk. Obesity has been a factor of contention among health-care providers and patients.[10] Our data suggest that overweight people have lower mortality rates than those of average weight. This finding accords with data suggesting that of patients with cardiovascular disease, those who are overweight have lower mortality rates,[11] and the major cause of early death after joint replacement is from cardiovascular causes.[12] However, almost 60% of data for body-mass index was missing and our data imputation assumes that the data are missing at random. Some of the data might not be missing at random and thus the results, though intriguing, should still be considered with some caution. We are interested to know if our findings can be replicated in other cohorts with more complete data about body-mass index.

The National Joint Registry is the largest arthroplasty register in the world, and has comprehensive coverage of all patients operated on, enhancing confidence in the generalisability of these findings (panel). The data are observational, so causality cannot be proven, but testing these findings with a randomised controlled trial is unfeasible and unethical. We were able to adjust for many probable confounders, although confounding by indication remains a possibility, particularly for the anaesthetic data. We would welcome the chance to test whether registries from other countries identify the same factors as affecting mortality—surgical practices probably differ between countries, thereby potentially changing the confounding factors and increasing our confidence that the associations we have identified are truly causal.

Panel: Research in context

Systematic review

We searched the Cochrane Library, Medline, and Embase, from 1995 to March 26, 2013, for studies of total hip arthroplasty and mortality. Our search terms related to total hip replacement, arthroplasty, prosthesis, and mortality. We found one systematic review,[13] seven national registry studies,[14–20] and four large institutional registry studies (>10 000 patients).[21–24] Three national registry studies[14–16] reported decreased in-hospital mortality over time. The systematic review analysed 80 studies that investigated mortality rates after hip or knee arthroplasty, and identified only non-significant trends of lower 90-day mortality in women than in men. The remaining registry studies[17–23] identified male sex, increasing age, higher numbers of comorbidities (specifically cardiovascular disease, cancer, psychosis or dementia, renal disease, cerebrovascular disease, pulmonary embolus, and chronic pulmonary disease), and ethnic origin as patient-related predictors of mortality. Although all these national registry studies were linked to national databases for identification of mortality, only two were linked to national databases that enabled accurate study of comorbidites, suggesting that any associations could have had underlying confounding.

Interpretation

The UK's National Joint Registry is the biggest joint replacement database in the world, enabling us to analyse more than 400 000 primary hip replacements. Linkage to Hospital Episode Statistics enabled us to carefully assess comorbidities, and therefore control for confounding. Our findings show that all-cause mortality at 90 days has decreased between 2003 and 2011, repeating previous findings of a reduction of in-hospital mortality. As for other registry studies, we have identified increasing age and male sex as predictors of mortality. Furthermore, we identified treatment variables that were associated with decreased mortality: spinal anaesthetic or a combination of spinal and another anaesthetic, posterior surgical approach, and use of mechanical or chemical thromboprophylaxis. Implant type had no effect on 90-day mortality. Thus, adoption of posterior surgical approach, mechanical and chemical prophylaxis, and spinal anaesthesia could, if causally related, reduce mortality further.

Contributors

LPH, YB-S, EMC, PD, AJ, AJM, JHT, and AWB designed the study. The data were extracted by Northgate (Hemel Hempstead, UK). LPH and KV managed and analysed data. EMC, YB-S, and AWB reviewed the published work. All authors interpreted data and wrote the report.

Conflicts of interest

We declare that we have no conflicts of interest.

Acknowledgments

The study was funded by the National Joint Registry. We thank the patients and staff of all the hospitals who have contributed data to the National Joint Registry. We are grateful to the Healthcare Quality Improvement Partnership, the National Joint Registry Steering Committee, and staff at the National Joint Registry centre for facilitating this work. The views expressed represent those of the authors and do not necessarily reflect those of the National Joint Registry Steering Committee or Healthcare Quality Improvement Partnership, who do not vouch for how the information is presented.

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